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Strangeness production in nuclear interactions at 200 A GeV and the number of nucleon-nucleon collisions

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Abstract. Data on mean numbers of Λ, $\bar{\Lambda}$, K's and on the total number $< s\bar{s} >$ of pairs of strange valence quarks in final state hadrons in hadronic and nuclear collisions at CERN-SPS energies are studied as a function of the mean number $< n_{coll} >$ of nucleon-nucleon collisions. Results give indications of an almost linear dependence over most of the region of $< n_{coll} >$. This in turn points out to strangeness being produced mostly in the central rapidity region of nucleon-nucleon collisions by a mechanism similar to a hard or semi-hard process. The available data are extrapolated to Pb+Pb interactions by two simple models, leading to $< s\bar{s} >_{Pb+Pb} \approx 300 \pm 30$. Observations exceeding these values of $< s\bar{s} >_{Pb+Pb}$ would give evidence of the onset of a new dynamical regime in Pb+Pb interactions.

1 Introduction

Production of strange particles in proton-proton (pp), proton-nucleus (pA) and nucleus-nucleus (AB) collisions has been extensively studied both experimentally and theoretically in the past decade.

The enhanced production of strange particles especially of antibaryons has been suggested as one of possible signatures of Quark-Gluon Plasma (QGP) formation see e.g. [1]. Alternative scenarios for strangeness enhancement are hadron gas (for review see [2,3]) and microscopic models (for reviews see [4–7]).

Ratios of mean numbers of Λ and K_s^0 per event over negative hadrons h^-, denoted as $< \Lambda > / < h^- >$ and $< K_s^0 > / < h^- >$ has been measured by NA-35 Collaboration [8,9] and found to be about twice as large as the same ratios in pA collisions [8–11]. Compilations of data can be found in [12–15].

An alternative, and in a sense global, point of view on strangeness enhancement consists in counting the total mean number $< s\bar{s} >$ of s- and $\bar{s}$-valence quark pairs in final state hadrons and studying the ratio [15–18]

$$\lambda_s = \frac{< s\bar{s} >}{0.5(< d\bar{d} > + < u\bar{u} >)}$$

The value of $< s\bar{s} >$ pairs is experimentally measurable and given as [15,17]:

$$\begin{aligned} < s\bar{s} > \approx 0.5(&< \Lambda > + < \Sigma > + < \bar{\Lambda} > + < \bar{\Sigma} > \\ &+ < K^0 > + < \bar{K}^0 > + < K^+ > \\ &+ < K^- >) + 2/3 < \eta > \end{aligned}$$

Analyzing the data on strangeness production in pp, pA and central S+S collisions Bialkowska et al. [15] have found that for central S+S interactions the value of λ_s is about twice as large as for pA interactions. For pA interactions (see Table 3. in [15]) $\lambda_s \approx 0.2$, whereas for central S+S interactions $\lambda_s = 0.36 \pm 0.03$

The dynamical mechanism responsible for hadron – and in particular for strange hadron production – is at present unknown and it is therefore difficult to see whether the increase of ratios $< \Lambda > / < h^- >$ and $< K > / < h^- >$ and of λ_s when going from pA to central S+S interactions is due to the formation of a new form of matter or whether it is due to more mundane reasons.

In order to obtain some hint into possible reasons of the observed strangeness enhancement we shall study in the next Sect. the dependence of $< \Lambda >$, $< \bar{\Lambda} >$, $< K >$ and $< s\bar{s} >$ on the mean number of nucleon-nucleon collisions $< n_{coll} >$ in pA and AB interactions.

The purpose of the present note is to show that $< \Lambda >$, $< K >$ and in particular $< s\bar{s} >$ depend linearly – with a mild attenuation increasing with the number of collisions – upon $< n_{coll} >$ what in turn indicates that strangeness is produced by a mechanism reminiscent of hard or semi-hard processes.

In Sect. 3 we shall present two simple, and basically rather similar, models describing strangeness production as a sum of contributions of individual nucleon-nucleon collisions. The models permit to extrapolate the available data to the case of Pb+Pb interactions and the difference between the two models gives a feeling of the error of extrapolation.

If data on $< s\bar{s} >$ in Pb+Pb interactions were substantially higher than these simple extrapolations we would have an evidence of an onset of a new dynamical regime between S+(heavy target) and Pb+Pb collisions.

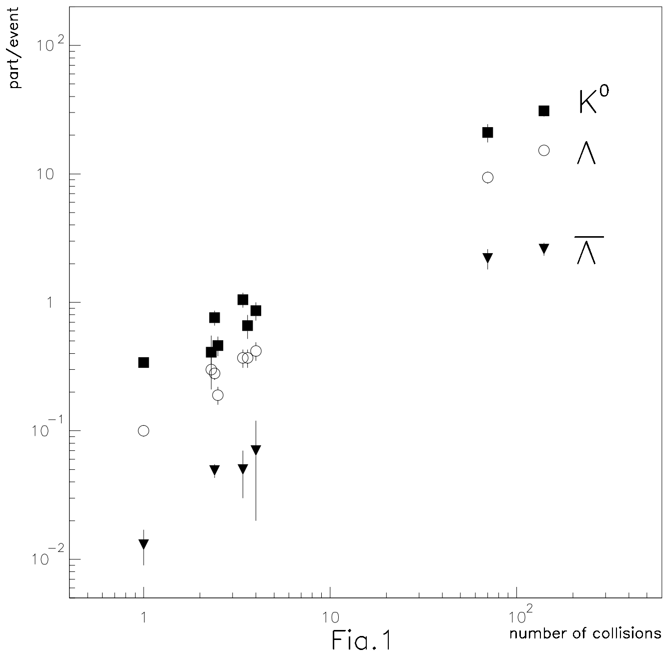

Fig. 1. The dependence of $<\Lambda>, <\bar{\Lambda}>$ and $<K^0>$ on the mean number of nucleon-nucleon collisions $<n_{coll}>$ for pp, pA and AB interactions. The data are from Refs. quoted in Table 1

The attenuated linear dependence of $<s\bar{s}>$, $<\Lambda>$, $<\bar{\Lambda}>$and $<K>$ on $<n_{coll}>$ is rather weird and we shall discuss a possible message of this phenomenon in Sect. 4.

2 Dependence of $<\Lambda>$, $<\bar{\Lambda}>$, $<K^0>$ and $<s\bar{s}>$ on the number of nucleon-nucleon collisions

In Fig. 1 we plot $<\Lambda>, <\bar{\Lambda}>$ and $<K^0>$ vs. the mean number of nucleon-nucleon collisions $<n_{coll}>$ for pp, pA and AB interactions. Values of $<n_{coll}>$ have been calculated by a simple Monte Carlo model of the Glauber type to be described in more details in the next Section.

The data were compiled from the original papers. The exact references are quoted in Table 1. It should be noted here that data of three experiments [9–11] are not consistent. This can be seen by comparing kaons in pAg from [11] with kaons in pXe in [10], kaons in pAr in [10] and kaons in pS [9]. Quoted number of kaons in the same experiment has also changed with increased statistics by more then 30% [8,9]. We take the value from the more recent publication.

The value of $<s\bar{s}>$ pairs in pp collisions is experimentally measurable and given as [15,17]:

$$<s\bar{s}>=<s\bar{s}>_B + <s\bar{s}>_M \quad (1)$$

where $<s\bar{s}>_B$ and $<s\bar{s}>_M$ are contributions from baryons and mesons respectively.

$$<s\bar{s}>_B \approx 0.5(<\Lambda> + <\bar{\Lambda}> + <\Sigma> + <\bar{\Sigma}>)$$
$$+ <\Xi> + <\bar{\Xi}>$$

where Λ stands for $\Lambda + \Sigma^0$, Σ stands for $\Sigma^+ + \Sigma^-$ and Ξ for $\Xi^0 + \Xi^-$ and correspondingly for the antiparticles.

Hyperon yields are not well known. An estimate of Σ hyperons is given by Wroblewski empirical formula [18] $<\Sigma>\approx(0.6\pm0.1)<\Lambda>$.

A rough estimate of Ξ hyperons can be obtained by extrapolating the ratio Ξ^-/Λ from lower energy data to 200 GeV/c and using the available information on Λ production at 200 GeV/c. For the extrapolation to $p_{lab} = 200$ GeV/c we use the value of Ξ^-/Λ ratio of 0.016 ± 0.011 at p_{lab} =19GeV/c [19] and 0.025 ± 0.007 at p_{lab} =28GeV/c [20]. Extrapolation is made linearly in $\sqrt{s}$ with the condition that the ratio should be always non-negative. The result is $\Xi^-/\Lambda = 0.0034\sqrt{s}$. For $p_{lab} = 200GeV/c$ we get $\Xi^-/\Lambda = 0.066$ Assuming that in pp collisions according to valence quark content of protons $\Xi^0/\Xi^- \approx 2$, the total Ξ contribution is $<\Xi^- + \Xi^0> \approx 3 * \Xi^-/\Lambda$ $<\Lambda>\approx(0.2\pm0.05)<\Lambda>$. In the $<\bar{\Xi}>$ sector the ratio $\bar{\Xi}^-/\bar{\Lambda} = 0.06\pm0.02$ at $\sqrt{s} = 63GeV$ was measured in [21]. For simplicity we shall use $<\bar{\Xi}>= 0.2<\bar{\Lambda}>$ which slightly overestimates $<\bar{\Xi}>$ contribution to $<s\bar{s}>_B$. The error on final $<s\bar{s}>_B$ is of the order of 1%.

For pp interaction at 200 GeV/c we thus have

$$<s\bar{s}>_B = (1.0\pm0.1)(<\Lambda> + <\bar{\Lambda}>)$$

and by using the compilation [14] this leads to $<s\bar{s}>_B = 0.109\pm0.015$.

The $<s\bar{s}>$ content of the meson sector can be approximated as

$$<s\bar{s}>_M \approx 0.5 * (<K^0> + <\bar{K}^0>$$
$$+ <K^+> + <K^->) + \frac{2}{3}<\eta>$$

where the $<\Phi>$ contribution is effectively included in kaons and $\eta\prime$ is neglected.

The η production was measured to be 0.20 ± 0.02 at p_{lab} = 400 Gev/c [22], 0.92 ± 0.58 at $\sqrt{s}$ =53GeV/c [23] and less then 0.2 at p_{lab} =69GeV/c [24]. Interpolating this linearly in $ln(s)$ to $p_{lab} = 200GeV/c$ we get $<\eta>= 0.18\pm0.05$

Summing up contributions of all mesons we get at p_{lab} = 200 GeV/c
$<s\bar{s}>_M = 0.52\pm0.08$

Following Bialkowska et al. [15] we define

$$R_{SB} = \frac{<s\bar{s}>_B}{<\Lambda + \bar{\Lambda}>}$$

and

$$R_{SM} = \frac{<s\bar{s}>_M}{<K>}$$

where

$$<K>= (2<K^0_s> + <K^+> + <K^->)/4$$

We estimate the total number of $s\bar{s}$ pairs produced in AB (pA) collisions as

$$<s\bar{s}> = R_{SB}(pp)<\Lambda + \bar{\Lambda}>_{AB}$$
$$+R_{SM}(pp)<K>_{AB} \quad (2)$$

Table 1. The dependence of the number of the strange quark pairs per event $< s\bar{s} >$ on the number of nucleon-nucleon collisions in pMg,pS,pAr,pAg, pXe,pAu,SS,SAg collisions calculated in model 1 (column 6) and model 2 (column 7). For comparison data are presented in column 5. In column 3 we give the number of nucleons participating at least in one collision (Part.) and the next column gives the number of nucleon-nucleon collisions (Coll.)

	p_{LAB}	Part.	Coll.	$\langle s\bar{s}\rangle$ DATA	$\langle s\bar{s}\rangle$ MOD 1	$\langle s\bar{s}\rangle$ MOD 2	Ref.
pp	200 GeV/c	2	1	0.63±0.08	–		
pMg	200 GeV/c	3.3	2.3	0.9±0.3	1.2	1.2	[11]
pS	200GeV/c	3.4	2.4	1.40±0.23	1.3	1.3	[9]
pAr	200GeV/c	3.5	2.5	0.84± 0.14	1.4	1.4	[10]
pAg	200GeV/c	4.4	3.4	1.9±0.3	1.7	1.7	[11]
pXe	200GeV/c	4.6	3.6	1.3± 0.3	1.8	1.8	[10]
pAu	200 GeV/c	5.	4.	1.7±0.30	1.9	1.9	[11]
SS	200GeV/c	56	72	38.0± 5.4	35	35	[9]
SAg	200GeV/c	89	135	55.5± 6.5	58	60	[9]
PbPb	160GeV/c	404	905	–	270	330	–

Our values of parameters R_{SM} and R_{SB} are

$$R_{SB}(pp) = 1.0 \pm 0.1 \qquad R_{SM}(pp) = 2.6 \pm 0.3$$

whereas Bialkowska et al. [15] have found

$$R_{SB}(pp) = 0.93 \pm 0.06 \qquad R_{SM}(pp) = 2.75 \pm 0.09$$

In our analysis of data on kaon production in nuclear collisions whenever experimental data on charged kaons were not available the $< K >$ value was calculated assuming that the relative yields of K^0_s, K^+ and K^- for a given AB (pA) reaction are the same as in nucleon-nucleon (proton-nucleon) reaction. We also take into account that for isospin zero system it holds $< K^+ > + < K^- > \approx 2 < K^0_s >$

In Fig. 2 we present the dependence of the mean number of $s\bar{s}$ pairs on $< n_{coll} >$.

Values of $< s\bar{s} >$ were calculated according to (2). The results agree with those of Bialkowska et al. [15] except for the pS value where we have taken more recent data [9].

The (2) was derived assuming that Λ and $\bar{\Lambda}$ are corrected for feed down from week Ξ and $\bar{\Xi}$ decays. This is not the case for the NA35 data used in our analysis. The effect of feed down can be estimated using the WA85 (SW collisions) and WA94 data (SS collisions) [25,26]. These data shows that about 10% of Λ are from Ξ and about 20% of $\bar{\Lambda}$ are from $\bar{\Xi}$. This will lower the $< s\bar{s} >$ values in SS and SAg collisions by about 4%.

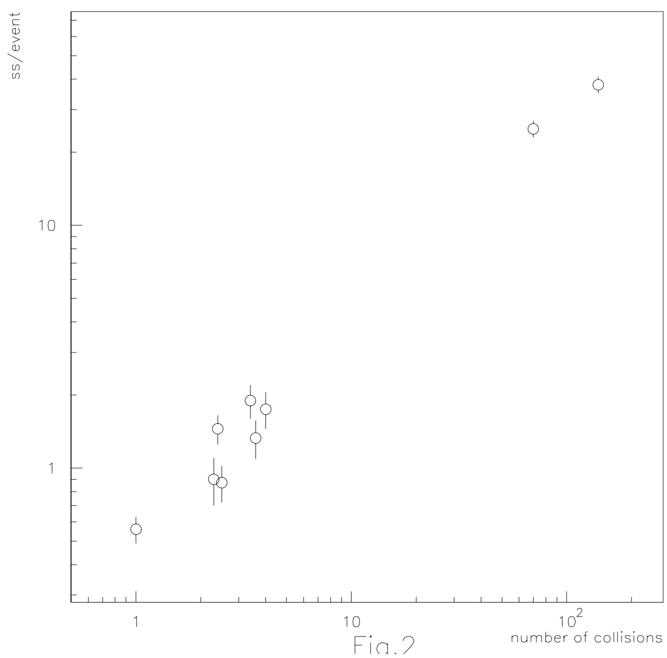

Fig. 2. The dependence of the mean number of $s\bar{s}$ pairs on the mean number of nucleon-nucleon collisions $< n_{coll} >$ for pp, pA and AB collisions. Data are taken from Refs. given in Table 1

3 Extrapolations of strangeness production to Pb+Pb interactions

In order to extrapolate strangeness production as described by $< s\bar{s} >, < \Lambda >, < \bar{\Lambda} >$ and $< K^0 >$ to the case of Pb+Pb collisions we shall first "parametrize" the data for collisions induced by lighter ions by a simple model.

Since the data on $< s\bar{s} >$ production are more stable with respect to final state interactions like $\bar{\Lambda}N \to K\pi$ or $\bar{K}N \to \Lambda\pi$ – although not with respect to $\pi N \to \Lambda K$ – we shall discuss here in detail only the case of $< s\bar{s} >$ dependence on $< n_{coll} >$.

Basic assumptions of our application of multiple nucleon-nucleon collision model to $< s\bar{s} >$ production in pA and AB collisions can be stated as follows:

a) $< s\bar{s} >$ in pA and AB interactions is given as the sum of $s\bar{s}$ pairs produced in individual nucleon-nucleon (nn) collisions, with the number of nn collisions calculated by the Glauber model. This assumption is equivalent to the statement that the contribution to $< s\bar{s} >$ due to "intrinsic strangeness" which appears in fragmentation of nucleon remnants after the last interaction of a nucleon is much smaller than the contribution due to $s\bar{s}$ production in nucleon-nucleon interactions. In this sense total strangeness production is assumed to be similar to hard or semi-hard processes and the number of strange quark pairs produced in AB interaction is in the first approximation proportional to the number of nucleon-nucleon collisions.

b) The proportionality is assumed to be modified by the attenuation of strangeness production with increasing number of previous interactions of the two nucleons participating in a nucleon-nucleon collision.

These assumptions require a few comments. Data [10, 11] on Λ production in pA interactions has been parametrized [10,11] as

$$\sigma^{\Lambda}_{pA} = A^{\alpha}\sigma^{\Lambda}_{pp} \tag{3}$$

with α close to 1. In a picture of multiple collisions where $s\bar{s}$ are produced in nucleon-nucleon interactions and the s-quark recombines with valence u- and d-quarks to form Λ such an A^{α} dependence is expected.

By making the assumption a) we are in fact extending to $s\bar{s}$ the description which is standard for production of $c\bar{c}$ and of heavier quark pairs. $c\bar{c}$ pairs are assumed to be produced by parton-parton, mostly gluon-gluon (gg) interactions. In the cms frame of nucleon-nucleon collision in the CERN SPS energy region, momentum fractions of gluons producing $c\bar{c}$ pairs are about $x = 0.15$. Cross-sections for these energetic gluons are rather small and the corresponding components of gluon structure functions are only very little attenuated during the passage of a nucleon through nuclear matter. Gluons responsible for $s\bar{s}$ production have lower values of x and we expect that the attenuation of the corresponding part of structure function would be larger than in the case of $c\bar{c}$ production. Because of that we have introduced also the assumption b). We shall determine the amount of attenuation by comparing the model with the data on p- and light ion-induced nuclear collisions. In order to estimate the errors of the extrapolation to the Pb+Pb case we shall study two parametrizations of the attenuation.

In the former version of our model (referred to as Model 1) we shall calculate the attenuation via the decreasing cms energy squared of nucleon-nucleon collision. In each collision the nucleon loses a part of its momentum and the energy squared (s_{ij}) for the collision which is i-th for one nucleon and j-th for the other one is decreasing with increasing i and j. The dependence of s_{ij} on i, j is parametrized as follows

$$y_{ij} = y_{beam} - [(i-1) + (j-1)]\Delta y_{lost}$$
$$s_{ij}/GeV^2 = 2 + e^{y_{ij}} + e^{-y_{ij}} \tag{4}$$

Values of $< s\bar{s} >$ as a function of s_{ij} are taken from the data on total strangeness production in pp collisions.

The model gives a useful parametrization of strangeness production but we cannot imagine that the nucleon in individual nucleon-nucleon collisions is slowed down as a whole and that its parton distribution is "rescaled" after every collision to the new value of nucleon's momentum. Such a picture would contradict [27] data on production of Drell-Yan pairs which show that momenta of valence (and in general faster) partons are not modified during the passage of nucleon through nuclear matter.

In the latter version of our model (referred to as Model 2) we shall simply assume that $s\bar{s}$ production in i-th collision of one nucleon and j-th collision of the other one is proportional to

$$(1-\beta)^{i-1}(1-\beta)^{j-1} \tag{5}$$

Physics behind this assumption is rather simple. We imagine that $s\bar{s}$ production is due to parton-parton (mostly gluon-gluon) interactions with gluon momenta of the order of 0.3–1.0 GeV/c in the nucleon-nucleon cms. In each nucleon-nucleon collision the number of gluons in a nucleon is depleted [28] by a fraction of $(1-\beta)$. This leads to attenuation of $s\bar{s}$ production in subsequent collisions.

In this note we shall not discuss the question of the production mechanism of pions, which is not well understood at present, since the data can be described both by the wounded nucleon model [12,29] and within the scheme of multiple nucleon-nucleon interactions [30].

We shall now present some details on the model of multiple nucleon-nucleon collisions we shall use in our computations.

A simple version of the multiple collision model has been introduced by C.Y. Wong [30–32]. It has been used to describe successfully total pA and AB cross sections [30], transverse energy distributions [33], rapidity and p_T distributions [30,34] and nuclear stopping power [35].

The assumptions of the model are

a) proton-nucleus and nucleus-nucleus collisions can be decomposed as a collection of nucleon-nucleon collisions.

b) positions of nucleons in nuclei are uniformly distributed within the sphere of radius $R_A = 1.2A^{1/3} fm$ (we check that changing uniform nucleon density to Wood-Saxon type density changes our results by less than 10%)

c) only binary collisions of target and projectile nucleons are considered (no rescattering)

d) the number of nucleon-nucleon collisions is governed by inelastic cross section of 3.2 fm^2.

The main virtue of the model is its simplicity. It is probably the simplest possible representation of nucleus-nucleus interactions in terms of nucleon-nucleon collisions.

In the former version of the parametrization of attenuation we use (4). The s-dependence of $s\bar{s}$ production in nucleon-nucleon collision is parametrized as

$$< s\bar{s} >= 0.38 * ln(\sqrt{s}) - 0.498 \tag{6}$$

where $\langle s\bar{s}\rangle$ is the average number of $s\bar{s}$ pairs per event as defined in (1). $s = (p_1 + p_2)^2/GeV^2$ where p_1 and p_2 are four momenta of colliding nucleons.

Equation (6) is taken to reproduce our $< s\bar{s} >$ value at 200 GeV/c and $< s\bar{s} >= 0.11 \pm 0.02$ from [18].

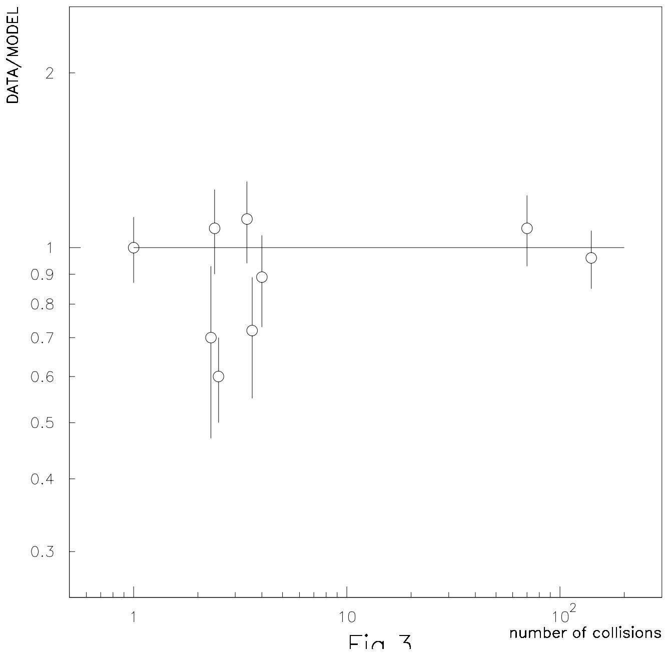

Fig. 3. The ratio of the data on $< s\bar{s} >$ in pp, pA and AB interactions and results of our two models. Within the values of $< n_{coll} >$ shown the models give almost identical results

The degradation of 'nucleon' momentum or better the degradation of that component of nucleon which is responsible for strangeness production is given by Δy_{lost} in (4). Comparison of data with Monte Carlo calculation based on the model of multiple nucleon-nucleon-collisions gives

$$\Delta y_{lost} \approx 0.35$$

Results of this version of the model are compared with data in Table 1.

Note that the value of Δy_{lost} is smaller than that obtained from the data on proton rapidity distributions (nuclear stopping power) or from pion rapidity distributions described within the Glauber model. We shall discuss this rather important point in the next Section.

In the second version of our model we describe the attenuation of the production of $s\bar{s}$ by (5) taking β as a free parameter. Proton- and light ion-induced data lead to

$$\beta \approx 0.12$$

A comparison of results of calculations with the data is given in Fig. 3 and in Table 1. As can be seen from Table 1 the extrapolation to the case of Pb+Pb interactions by using the two models leads to $< s\bar{s} >= 330$ in Model 2 and to $< s\bar{s} >= 270$ in Model 1. Taking the difference between the two models as an indication of the magnitude of the error of extrapolation, the measurement of $< s\bar{s} >$ outside of the interval $< s\bar{s} > = 300 \pm 30$ in Pb+Pb interactions would provide an evidence of the onset of a new dynamical regime.

For consistency check we present in Table 1 also the numbers of participants and collisions.

4 Comments and conclusions

The attenuated linear dependence of $< s\bar{s} >$ and of $< \Lambda >$, $< K >$ and $< \bar{\Lambda} >$ on $< n_{coll} >$ is rather difficult to understand, since it is similar to that of hard or semi-hard processes, like J/Ψ and Drell-Yan pair production. The inclusive cross-section for e.g. $< \Lambda >$ production in pA collisions is given as

$$\sigma^{\Lambda}_{pA} =< \Lambda >_{pA} \sigma_{pA} \qquad (7)$$

With $< \Lambda >_{pA} \sim < n_{coll} > \sim A^{1/3}$ and $\sigma_{pA} \sim A^{2/3}$ we obtain $\sigma^{\Lambda}_{pA} \sim A^{\alpha}$ with α close to 1, which is just the experimental result in (3). Approximate proportionality of $< \Lambda >$ to the number of nucleon-nucleon collisions is thus an experimental fact for pA interactions. Our results in Figs. 1-3 and in Table 1 just show that this approximate proportionality can be extended also to the case of AB interactions. The proportionality indicates that in AB collisions final state interactions do not strongly modify particle fractions. This is less surprising for $< s\bar{s} >$ since it gets changed only by reactions like $\pi N \to K\Lambda$ than for $< \Lambda >, < \bar{\Lambda} >$ and $< K^0_s >$ which are influenced also by processes like $N\bar{\Lambda} \to K\bar{N}N$ and $\bar{K}N \to \Lambda\pi$. The failure of this simple picture for Pb+Pb interactions would give evidence for the onset of a new dynamical regime which would lead, via final state interactions, or QGP to $< s\bar{s} >$, $< \Lambda >$, $< \bar{\Lambda} >$ and $< K >$ very different from the expectations based on the simple model described above. Such an evidence would complete the one already given by the data of NA-50 Collaboration on J/Ψ suppression [36].

In analyzing data on $< s\bar{s} >$ production we have used two models referred to as Model 1 and Model 2.

In the latter the attenuation is of $s\bar{s}$ production in subsequent nucleon-nucleon collisions has been parametrized by (5) with a rather simple interpretation described below (5). For a truly hard process, like e.g. Drell-Yan pair production, one would obtain β=0. The value we have found from data on $< s\bar{s} >$, $\beta \approx$0.12 indicates that the $s\bar{s}$ production for light-ion (up to Sulphur) induced nuclear interactions may be viewed as a hard process with the attenuation factor given by (5).

The former model, specified by (4) and (6) parametrizes $s\bar{s}$ production in a way frequently used for describing soft processes, like pion production, in the Glauber model. A hard process, like Drell-Yan production, can be described also in this scheme by chosing Δy_{lost}=0. The value of the parameter Δy_{lost} found in our analysis is significantly lower than the value usually obtained in analyses of data on pion production or nucleon rapidity distributions, which are typically in the interval 0.7–1.0. A particular case will be mentioned shortly. Lower value of Δy_{lost} found in our analysis of $s\bar{s}$ production indicates that $s\bar{s}$ pair are originated by a mechanism which is harder than that responsible for pion production.

In a recent study Jeon and Kapusta [37] (see also the preceding work [38,39]) have used a Glauber model approach to describe nucleus-nucleus interactions as a sequence of binary nucleon-nucleon collisions. They have obtained agreement with data on proton and negative hadron rapidity and transverse momentum spectra but failed to reproduce data on production of strange particles in S+S interactions. They have obtained only 80% of observed charged kaons, 50% of observed neutral kaons and Λ's and 10% of observed $\bar{\Lambda}$'s. The difference between their results and ours can be traced back to the value of the parameter Δy_{lost}. The value of Δy_{lost} used by Jeon and Kapusta [37] is much larger than ours. In particular for proton-nucleus interactions the value of rapidity loss of the incoming proton in each nucleon-nucleon collision as calculated from the (13) in [37] is 0.6 units of rapidity.

The comparison of these values with Δy_{lost}=0.35 found in our analysis of $s\bar{s}$ production indicates again that $s\bar{s}$ pairs are produced by a mechanism which is harder than pion production and nucleon deceleration.

The discrepancy between values of Δy_{lost} corresponding to pion and $s\bar{s}$ production indicates that different components of the nucleon structure function are attenuated differently during the passage of a nucleon through nuclear matter.

Finally let us compare our picture of $s\bar{s}$ production with other models. An approach based on the wounded nucleon model has been presented by Kacperski [40]. The author considers three types of nucleon-nucleon collisions: fresh-fresh, fresh-wounded and wounded-wounded. Strange particle production in these three types of collisions is different. This allows to fit data on strangeness production. In our model the production of total strangeness in a particular nucleon-nucleon collision depends on the number of preceding collisions of both nucleons and not only on whether the nucleon is wounded or not.

Another phenomenologically successful description of data motivated by the additive quark model has been presented by Kadija et al. [41]. The number of produced Λ's and $\bar{\Lambda}$'s is assumed to be proportional to the number of collisions of constituent quarks. Each nucleon can provide at most three constituent quarks. In order to describe data one has to introduce rescattering in the final state.

Our picture is close to that of Kadija et al. [41] in assuming that strangeness is produced by a mechanism which is harder than presumably rather soft fragmentation process.

Geist and Kachelhoffer [42] study production of strange particles in pA collisions and parametrize the A-dependence of production cross section by

$$A^{0.8-0.75x+0.45x^3/|x|}$$

where x is the momentum fraction carried by a strange particle. This leads to $A^{0.5}$ dependence in the forward region, to $A^{0.8}$ in the central region and to $A^{1.1}$ in the backward region. This parametrization is more detailed than ours but when integrated over x such a dependence on A seems to be compatible with our version of the multiple collision model with attenuated $< s\bar{s} >$ production. The x-distribution of final state strange hadrons is influenced by the recombination process and the strange quark picked up by two valence quarks may have a value of x typical for the fragmentation region. Thus although $s\bar{s}$ pair is produced originally at small x, the Λ and $\bar{\Lambda}$ carrying s and $\bar{s}$ may have quite different value of x.

Capella et al. [43] has shown that rapidity distribution of Λ and $\bar{\Lambda}$ as observed in nucleus-nucleus collisions at the CERN SPS, can be reproduced by the independent string model with diquark-antidiquark pairs in the sea, flavour symmetric quark sea and with final state interactions of secondary hadrons. These final state interactions are responsible for the increase of Λ production via $\pi N \to K\Lambda$. The model of [43] is based on a different picture of strangeness production than ours and a direct comparison is impossible. Let us note only that the presence of final state interactions of the type $\pi N \to \Lambda K$ would bend the curves in Fig. 1 upward for higher values of AB.

Models based on string fusion [4,6] combined with final state interactions cannot be directly compared with our simple picture of attenuated gluon-gluon interactions.

Before concluding let us make a comment concerning a possible origin of the attenuated linear dependence of $< s\bar{s} >$ on $< n_{coll} >$. In the Geiger partonic cascade model [44] of heavy ion collisions in the CERN-SPS energy region the perturbative QCD parton production provides an important contribution to the rapidity density of final state particles in the central region [45]. Being harder than fragmentation the partonic cascade may lead to an increased $< s\bar{s} >$ production.

To conclude: we have shown that a simple model based on two main assumptions namely

a) nucleus-nucleus interactions of protons and lighter ions can be considered as superpositions of incoherent nucleon-nucleon collisions, the total strangeness being given as a sum of contributions of nucleon-nucleon interactions

b) cross-section for production of strange quarks pairs in nucleon-nucleon collision is attenuated with the increasing number of preceding collisions.

can consistently describe, within 1-2 std. errors, data on total strangeness production in proton-nucleus and nucleus-nucleus collisions up to S+Ag. The discrepancy between the value of Δy_{lost} found from $s\bar{s}$ production and that from pion rapidity distributions indicates that different components of nucleon structure function are attenuated differently during the passage of nucleon through nuclear matter.

The extrapolation of the model to the case of Pb+Pb interactions, together with the estimate of the extrapolation uncertainity based on the difference between the two versions of the attenuation, provides an estimate of total strangeness production in Pb+Pb interactions in a situation where no new dynamical regime sets on:

$$< s\bar{s} >_{Pb+Pb} \approx 300 \pm 30$$

Data larger than this estimate would give an evidence of the presence of a new dynamical regime, complementing the one provided by data on J/Ψ suppression [36].

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